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ENTOMOLOGICAL PHASES OF THE 1959 LODGEPOLE NEEDLE MINER CONTROL PROJECT IN YOSEMITE NATIONAL PARK

By

Robert E. Stevens and George R. Struble

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U. S. DEPARTMENT OF AGRICULTURE -- FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

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U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Division of Forest Insect Research

ENTOMOLOGICAL PHASES OF THE 1959 LODGEPOLE NEEDLE MINER CONTROL PROJECT IN YOSEMITE NATIONAL PARK

By

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SUMMARY

In 1959 the Yosemite National Park carried out an aerial spraying program for control of the lodgepole needle miner in the Tuolumne Meadows area. Some 3,400 acres of an aggregate infestation of about 62,000 acres, were treated with 2 pounds of malathion in 20 gallons of diesel oil per acre, in an effort to stave off impending catastrophic loss of the lodgepole pine forest in this highly used recreational area. Spraying was directed against two of the insect's developmental stages - the adults or moths, and the first-instar larvae.

The Forest Service cooperated by furnishing the Park with guidance on the entomological phases of the project. This included recommending the insecticide to be used, timing its application with respect to insect development, calibrating the aircraft spray systems, and measuring the effectiveness of the control.

On the areas sprayed during the moth stage, the control (corrected for natural mortality in unsprayed areas) was 89.9 percent. On the areas sprayed during the larval stage the corrected percent control was 69.7. Previous results with malathion sprays against the needle miner have shown that 70 percent has given good stand protection for at least 2 years. It is expected that the 1959 spraying will provide equal, if not better, protection.

INTRODUCTION

During July and August 1959, 3,400 acres of lodgepole pine forest in the vicinity of Tuolumne Meadows, Yosemite National Park, California, were aerially sprayed to control the lodgepole needle miner, Recurvaria milleri Busck. The spraying project was administered by the Yosemite National Park. Technical assistance on entomological matters was furnished to the Park by the Division of Forest Insect Research, Pacific Southwest Forest and Range Experiment Station. This report covers the entomological phases of the project.

Lodgepole pine forms the predominant forest cover in the Tuolumne Meadows area, and is the preferred host of the needle miner. The needle miner is no newcomer to Yosemite - four epidemics have been recorded since 1900. Each of these has been complicated by a subsequent outbreak of the mountain pine beetle, Dendroctonus monticolae Hopk. While the needle miner alone is capable of killing trees through the effects of defoliation, in Yosemite it appears more common for the mountain pine beetle to move in and deliver the "coup de grace" to trees which have been weakened by several successive defoliations. Consequently, much of the mortality can be attributed to the combined attack of the two insects - needle miner and bark beetle.

Research on the needle miner has been carried out during several of the recorded outbreaks. Current studies have been going on since 1954, and a number of progressively encouraging control tests have been conducted. 1/ The pertinent results of these tests can be boiled down as follows: Needle miner adults and first-instar larvae can be controlled to an acceptable degree with an aerial spray of malathion, applied at the rate of 2 pounds of the insecticide in 20 gallons of diesel oil per acre. Helicopters, primarily because of their maneuverability and their ability to operate from bases near the treating area, are superior to fixed-wing aircraft for applying the spray. (Only within the past 2 years, however, have sufficiently powerful machines been available that will carry a worthwhile amount of spray at the 9,000-foot elevation of the control area.)

Tuolumne Meadows, which is a rallying point for thousands of hikers, riders and campers each year, lies directly in the path of the current infestation, which now extends over some 62,000 acres. Destruction of the forest cover around the Meadows has appeared to be imminent. Realizing the possibility of losing essentially the whole stand to the needle miner and the bark beetle, and having a tested method at last by which the trees could be saved from destruction, the Park in 1958 decided to treat a portion of the infested area to save the trees in and around the sections of highest recreational value. With defoliation reduced, it was felt that mountain pine beetle control work could become increasingly effective, and the impending wholesale devastation would be averted. These are the conditions under which the 1959 needle miner control project was conceived. Its objective was not to control the entire infestation, but to protect the areas having the highest recreational values.

The Forest Service cooperated in furnishing technical help throughout the operation. Station personnel involved were: C. B. Eaton, R. C. Hall, G. R. Struble, R. E. Stevens, G. C. Trostle, B. E. Wickman, C. J. DeMars, and R. W. Bushing, along with seasonal employees, E. Jessen, L. D. Anderson, G. T. Ferrell, Chas. Schaefer and D. Linsdale.

1/ Trostle, G. C. and C. B. Eaton, 1958. Progress Report. Tests with insecticides to control the lodgepole needle miner, 1956 and 1957 seasons. Calif. Forest and Range Expt. Sta., Berkeley, Calif. 22 pp., illus. (Processed.)

Eaton, Hall, Struble and Trostle were responsible for the overall planning of the Station's part of the job. Stevens provided technical direction on the ground, and Struble developed the information necessary to time the spray application. Struble, Hall, Wickman, DeMars and Bushing, along with the seasonal employees, assisted Stevens in measuring the effectiveness of the control.

The Station's primary responsibilities in this project included:

1. Recommending the insecticide formulation.
2. Assisting in delineating the spray units.
3. Determining the optimum timing for spray application.
4. Calibrating the aircraft spraying systems.
5. Assisting in checking spray coverage.
6. Evaluating the effectiveness of the control.

PREPARATION FOR THE PROJECT

PLANS

During the winter of 1958-59, plans for the spraying operation were drawn up. 2/ A control area of roughly 4,000 acres was outlined by the Park on the basis of status of the needle miner and mountain pine beetle infestations, and the amount and character of public use. The more remote areas, no matter what the status of the infestation, were not considered for control.

Inasmuch as two developmental stages of the insect are vulnerable to the spray, it was decided to divide the project so that part of the spraying could be done against each stage. There were two reasons for this. First, considering the acreage involved and the expected number of spraying hours per helicopter per day, it was evident that there would not be enough suitable helicopters readily available to do the entire job against one stage in the time available. The time available, of course, was dictated by the insects' speed of development. Second, since the period during which the first-instar larvae are vulnerable generally follows Labor Day, after which travel is greatly reduced, it was only reasonable to minimize inconvenience to the public by planning to spray campgrounds and roadsides then. In the plan, about 1,000 acres were designated for spraying during the moth stage, and 3,000 acres during the larval stage (figures 1 and 2).

2/ Hall, R. C. and G. R. Struble, 1959. Plan for the technical phases of the 1959 lodgepole needle miner control project in Yosemite National Park. Pac. Southwest Forest and Range Expt. Sta., Berkeley, Calif. 6 pp. (Processed)

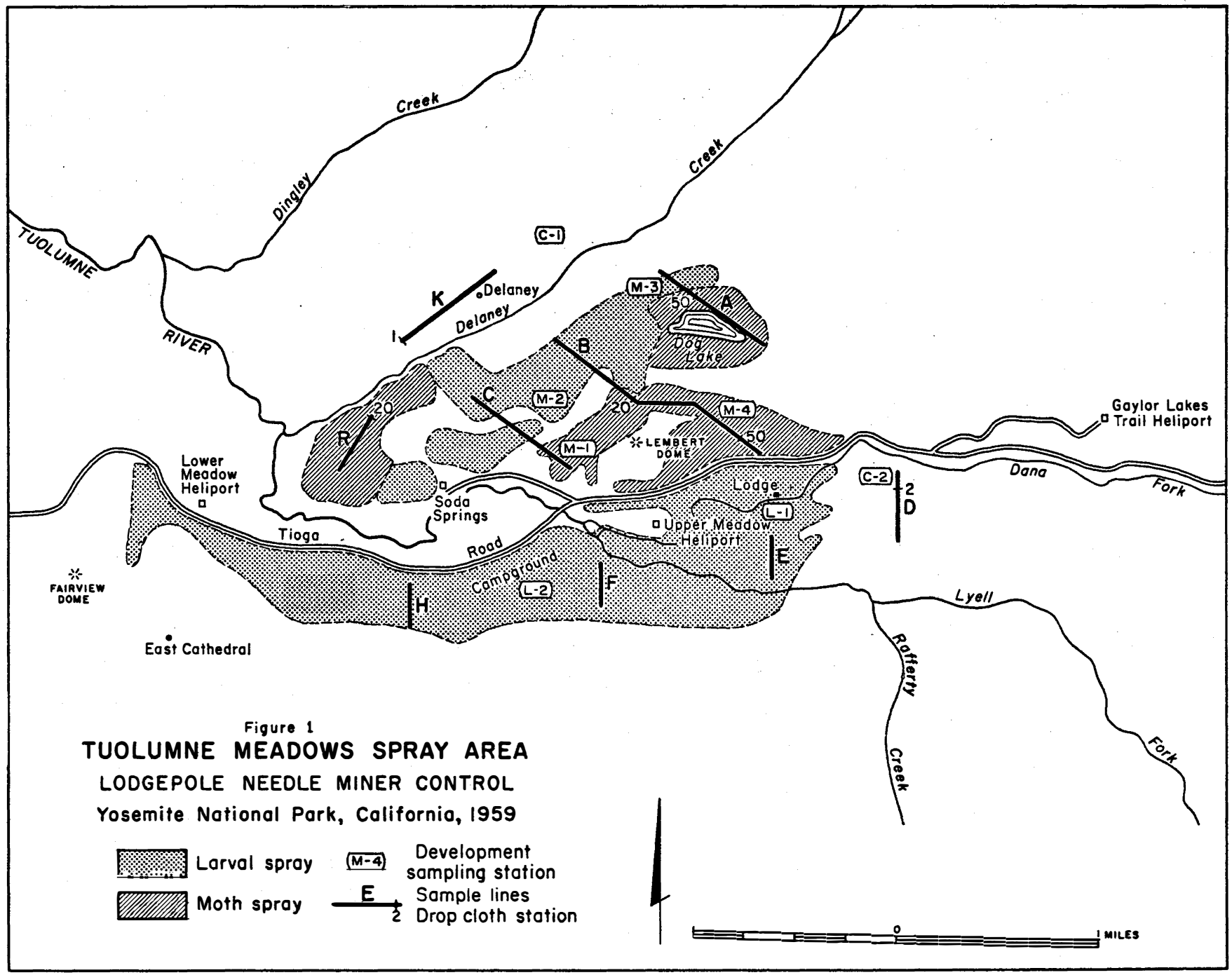

Figure 1

TUOLUMNE MEADOWS SPRAY AREA

LODGEPOLE NEEDLE MINER CONTROL

Yosemite National Park, California, 1959

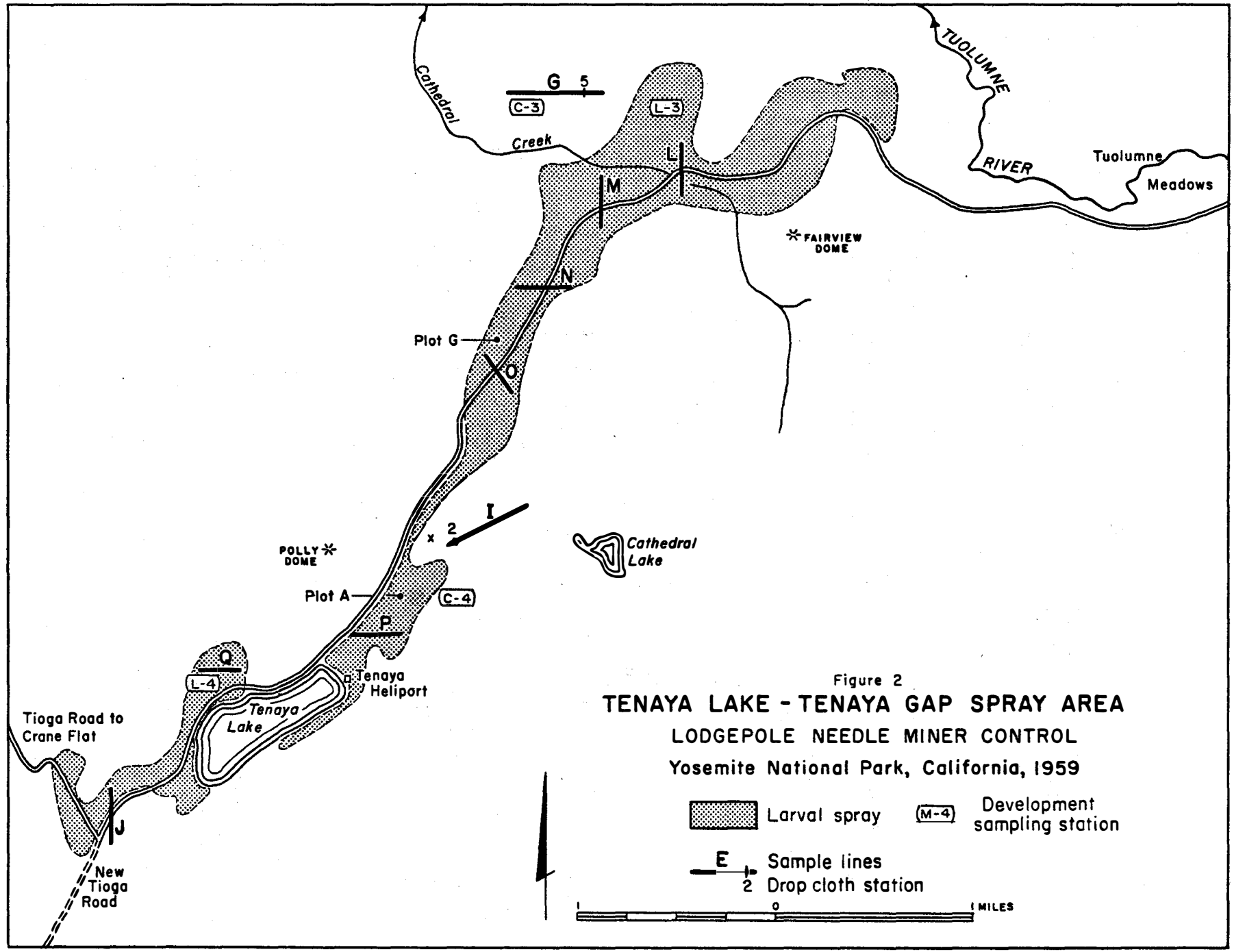

Figure 2

TENAYA LAKE - TENAYA GAP SPRAY AREA

LODGEPOLE NEEDLE MINER CONTROL

Yosemite National Park, California, 1959

DELINEATING SPRAY UNITS

The general delineation of the area to be sprayed was done jointly by the Park and Station people involved in planning the operation, early in 1959. The detailed work of setting up individual spray units and determining their acreages was done by Stevens, in cooperation with Park foresters, at Tuolumne Meadows in July.

Aerial photos were used for the detailed part of the job. Ektachrome transparencies of the Tuolumne Meadows area, scale $5\frac{1}{2}$ inches = 1 mile, had been obtained by the Park several years previously and these were used in laying out the spray blocks around the Meadows. The Park had the remainder of the area from Tenaya Gap to Tenaya Lake photographed in July 1959 with aerial Ektacolor, scale 6 3/8 inches = 1 mile. Prints made from these photos were secured in transparent celluloid envelopes, and the spray units outlined on the envelopes in wax pencil.

Spray unit boundaries were set up by use of a stereoscope, in conjunction with some field scouting. Boundaries were dictated primarily by topographic features such as ridges, domes, and streams, but in some cases roads and concentrations of buildings were utilized. As an aid to the pilots when applying the spray, an attempt was made to draw the spray units so each could be outlined on a single photo.

From the Ektachrome transparencies, the Station's Forest Survey unit made a planimetric map of the Tuolumne Meadows part of the project area, and the acreages of the spray units were determined from this map by using a dot grid. For the Tenaya Gap - Tenaya Lake part, where Ektacolor was used, the horizontal distortion was not great and acreages were dot-gridded from a mosaic overlay made on tracing paper directly from the photos. Unit size varied from 7 to 384 acres. Some of the smaller units ended up being flown as one and some of the larger ones were further subdivided.

SPRAY TIMING

In planning the control project, it was foreseen that target dates for beginning and ending spraying would be critical, both for the moths and the larvae. The periods when these two stages are most vulnerable are short. Moreover, they do not occur at exactly the same time each year, since variations in environmental conditions influence biological events in the life of the needle miner just as they do other organisms. The spraying schedule, therefore, was geared to the development of the insect, rather than to the calendar alone. This necessitated keeping detailed records of adult and larval development.

MOTH TREATMENTS

Knowledge of the emergence pattern and egg-laying habits of the adult needle miners indicated that spraying against this stage should begin soon after the moths began to appear, but that it should terminate before the bulk of the eggs were laid. The project plan, therefore, called for starting the spraying within 5 days after 5 percent of the moths had emerged, and ending the operation 10 days after it was started.

To find out when moth emergence reached the proportions specified, two techniques were used. One was to sample the population in the field periodically and determine what percentage of the insects in each sample had reached adulthood. The other was to cage infested material at the Tuolumne Meadows field laboratory and observe emergence directly. In the latter case, the rate could not be determined until all of the insects had emerged, so that in practice timing of the spraying hinged largely upon field sampling.

Population samples were taken at eight collection stations distributed throughout the project area as shown in figures 1 and 2. Four of the stations (M-1 to M-4) were in stands to be sprayed and four (C-1 to C-4) in unsprayed stands. At each station branch tips taken at mid-crown level from infested lodgepole pine were collected daily - one tip from each of 15 trees. Five needles with needle miners were removed from each tip, making a total of 600 needles examined each day.

Needles containing miners were readily detected by candling them before a strong light. The pupae showed as deep black bodies within the hollowed out needles. They were easily differentiated from the larvae which were lighter colored and longer. Under the microscope each needle was opened and the status of the insect noted (i.e., larva, pupa, or empty pupal case). Living pupae were differentiated from dead ones by the copious flow of yellowish fluid issuing from them when they were punctured. Moth emergence was determined by counting the number of empty pupal cases. The percent emergence at each collection station was plotted on a chart.

Sampling began on July 3, three days after the first adult was observed, and was continued daily thereafter until the emergence at each station was 80 percent or more. The last samples were taken on July 25. Soon after sampling started, the number of adults emerging began to increase each day, and by July 10 the average emergence for all stations approached 5 percent (table 1). This was the signal for alerting the Park to begin spraying by July 15. Emergence increased sharply around the 10th, the rise beginning first at the lower elevations and somewhat later at the upper elevations. By July 19-25, most of the needle miner population had reached the adult stage.

The first eggs were observed in samples from the lower elevations on July 13. Thereafter small numbers of eggs were found in some

Table 1.--Daily moth emergence during July in sprayed and unsprayed areas, by stations 1/ 2/

Date	Sprayed				Unsprayed			
	M-1 (8600)	M-2 (9000)	M-3 (9200)	M-4 (9000)	C-1 (9200)	C-2 (8800)	C-3 (8300)	C-4 (8200)
	--Percent--				--Percent--			
July 3	0	0	3	0	1	0	4	3
5	4	0	3	0	0	-	-	-
6	0	0	0	0	3	0	1	0
7	7	0	0	0	1	0	0	1
8	11	0	0	8	4	10	0	8
9	1	0	0	1	1	7	19	7
10	4	0	0	0	6	19	21	3
11	24	3	3	0	1	49	48	4
12	21	13	3	11	3	24	68	24
13	41	14	13	1	1	41	33	31
14	63	12	3	21	3	39	58	24
15	60	28	9	21	0	38	68	41
16	87	33	13	40	4	72	80	26
17	69	73	44	39	59	79	77	71
18	95	67	33	55	49	69	65	55
19	95	88	77	80	41	83	91	73
20	-	86	83	84	43	-	-	95
22	-	-	-	-	59	-	-	-
23	-	-	-	-	83	-	-	-
24	-	-	-	-	85	-	-	-

1/ Elevation indicated for each station.
2/ Based on examinations of 75 infested needles per station per day.

of the samples each day, but they did not turn up in the samples from the higher elevations until toward the end of the spray period. The prevalence of eggs helped to confirm the date for terminating spraying against the moths.

Studies of caged material, the second approach to determining the emergence pattern of the moths, supplemented the records obtained from field sampling. In these studies, 100 infested tips from each of six different locations were collected and brought to the Tuolumne Meadows field laboratory. There each lot of material was caged separately and the number of moths appearing in the cages was collected and recorded by sex three times daily.

The pattern of moth emergence in these rearings (figure 3) was essentially the same as that shown by the field samples. The rearings also showed

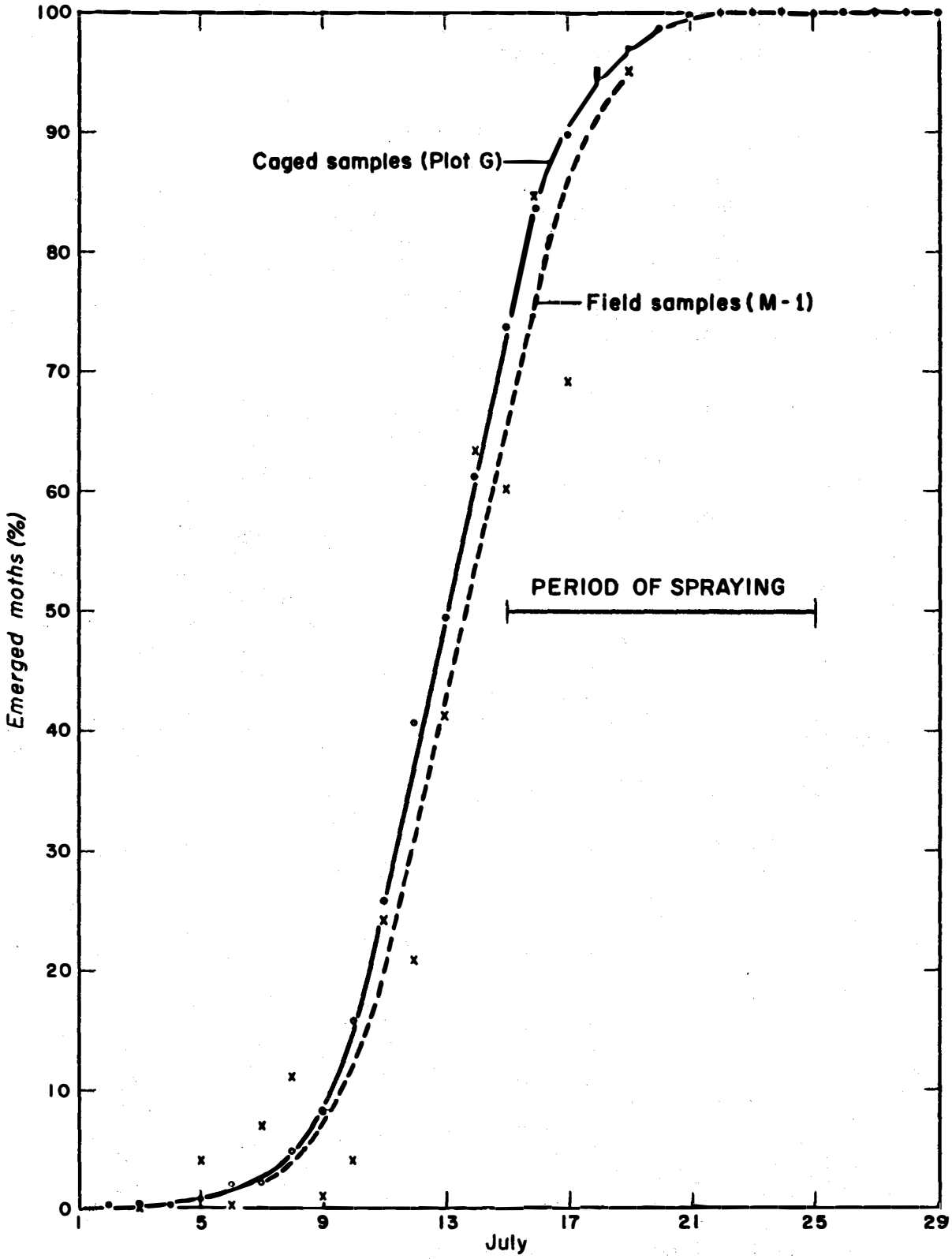

Figure 3.--Cumulative daily emergence of needle miner moths from field samples versus caged tips.

that the males emerged first and became fairly abundant before the bulk of the females appeared (figure 4).

LARVAL TREATMENTS

Results of previous tests had shown that malathion was most effective against the larvae when spraying was done about the time the eggs hatched. The hatching date was known to fall between 5 and 15 days after the eggs reached the black-headed stage. Accordingly, the project plan specified that the larval treatments should start within 5 days of the time when 80 percent of the eggs reached this stage, and continue no longer than 10 days from the time spraying began.

Population samples were taken periodically to determine how fast the eggs developed. As in the moth sampling, eight stations distributed throughout the project area were used, (figures 1 and 2). Four (L-1 to L-4) were in the area sprayed. The four in unsprayed stands were the same as those used for the moth samples. The number and method of obtaining infested tips was likewise the same.

Exploratory work to determine where eggs were most likely to be found showed that partly mined needles contained eggs twice as often as those mined the greater part of their length. The needles most often having eggs were those with a green base and 50 percent or less of their length mined. To obtain egg samples, needles of this type were plucked from the tips and candled to eliminate those with pupal cases or parasitized larvae, since the latter rarely contained eggs. The remaining needles were slit open under the microscope and the number and condition of any eggs found were recorded. As a rule, between 2 and 6 needles of the type favored for oviposition were found on each tip.

Eggs that had reached the blackheaded stage were easily differentiated from those that had not. When they are first laid the eggs are lemon yellow in color. As they reach the blackheaded stage, the chorion or egg covering becomes transparent, revealing the fully formed larva within. After hatching commenced, empty chorions often were found in the samples.

The first series of egg samples were collected July 22-23, approximately 10 days after eggs were first observed in the field. The second collection was made July 27-28. Thereafter, beginning on August 4, the samples were collected twice weekly through August 27. The number of eggs in the blackheaded stage approached 80 percent at the lower elevations about August 10. The data for the stations adjacent to Tenaya Lake, for example, indicated that 73 percent of the eggs had reached this stage at all except the highest elevations sampled (table 2 and figure 5). Some hatched eggs were noted at all locations prior to this date. The fact that hatching was starting was substantiated by observation on eggs held in petri dishes at the laboratory. Consequently, the alert to start spraying by August 15 was given.

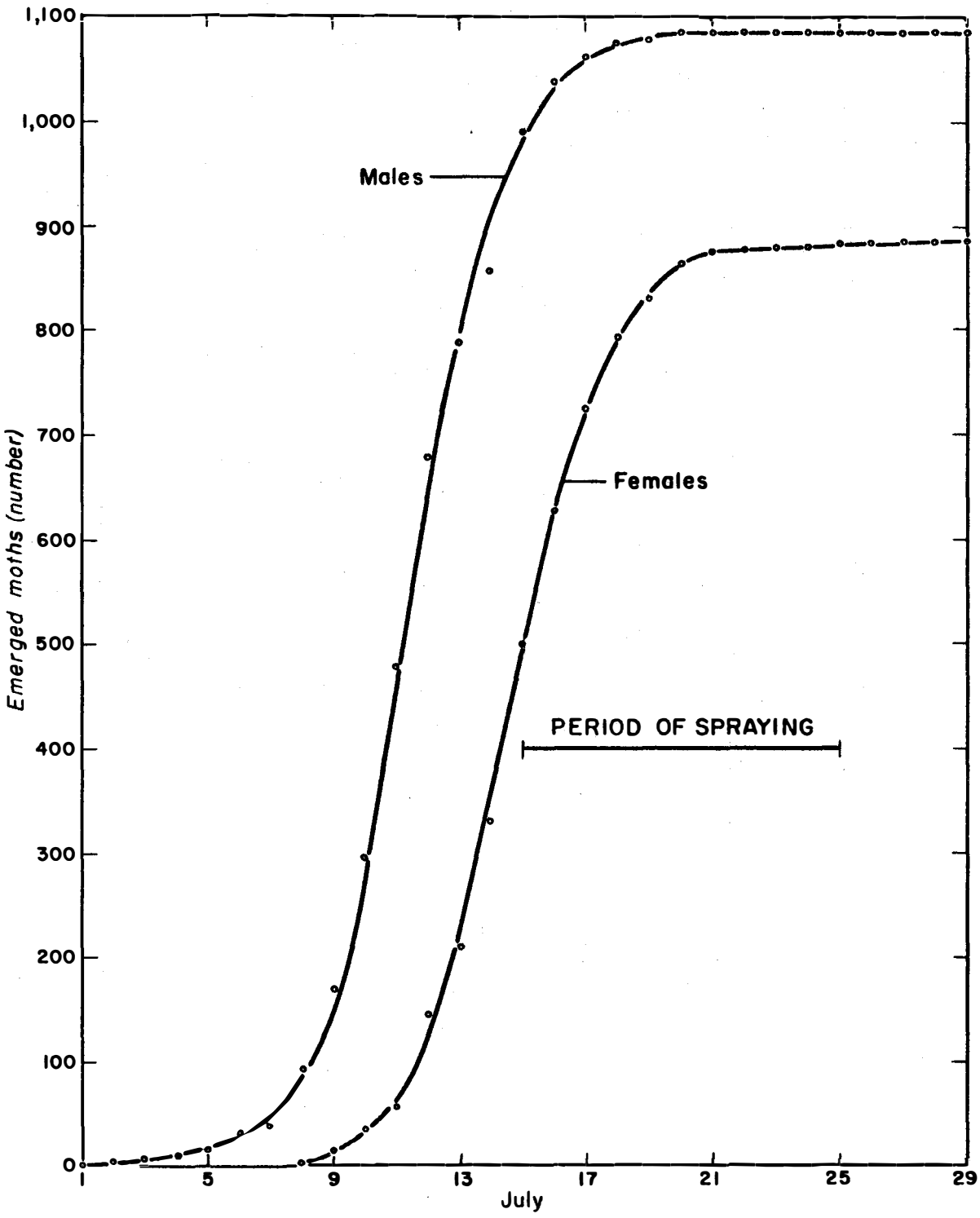

Figure 4.--Cumulative daily emergence of male and female needle miner moths from 100 caged tips (Plot G).

Table 2.--Egg development status on different sampling dates at stations in sprayed and unsprayed areas

Date	Sprayed				Unsprayed			
	Station 1/	Eggs sampled	Black-headed	Hatched 3/	Station 2/	Eggs sampled	Black-headed	Hatched 1/
1959		Number	Percent	Percent		Number	Percent	Percent
Aug. 4	L-1	354	0	0.0	C-1	217	0	0.0
	L-2	281	0	0.0	C-2	130	0	0.0
	L-3	494	3	0.4	C-3	296	3	0.0
	L-4	1,338	26	2.5	C-4	205	26	0.0
Aug. 6	L-1	297	26	2.0	C-1	125	0	5.6
	L-2	471	5	0.4	C-2	92	9	1.1
	L-3	342	41	2.6	C-3	164	23	0.0
	L-4	1,929	55	5.2	C-4	289	4	2.8
Aug. 9	L-1	117	62	1.7	C-1	200	14	1.0
	L-2	452	49	7.7	C-2	230	65	1.7
	L-3	618	57	0.6	C-3	1,188	70	6.3
	L-4	1,117	73	6.4	C-4	715	32	1.1
Aug. 13	L-1	256	85	7.4	C-1	122	2	0.0
	L-2	638	56	3.8	C-2	103	63	7.8
	L-3	1,124	74	5.7	C-3	679	75	6.9
	L-4	665	84	4.2	C-4	253	13	10.7
Aug. 17	L-1	294	94	9.8	C-1	255	11	4.3
	L-2	196	81	15.3	C-2	127	100	37.0
	L-3	297	12	10.4	C-3	497	93	4.6
	L-4	693	93	5.2	C-4	98	56	3.1
Aug. 20	L-1	424	87	12.5	C-1	42	15	42.9
	L-2	254	77	20.0	C-2	96	90	30.2
	L-3	534	78	1.1	C-3	666	90	3.9
	L-4	833	96	3.1	C-4	238	76	2.1
Aug. 24	L-1	433	94	19.4	C-1	259	32	7.3
	L-2	215	84	12.6	C-2	112	100	35.7
	L-3	324	88	14.8	C-3	1,121	93	12.2
	L-4	362	95	17.9	C-4	163	68	20.2
Aug. 27	L-1	186	99	22.0	C-1	304	59	9.9
	L-2	159	93	16.9	C-2	64	100	23.4
	L-3	357	80	7.8	C-3	328	97	22.3
	L-4	520	97	23.8	C-4	130	75	11.5
	TOTAL	16,574				9,508		

1/ Elevations respectively 86,000, 8,800, 8,300, 8,100.
2/ Elevations respectively 9,200, 8,800, 8,300, 8,100.
3/ Approximation based on count of empty chorions.

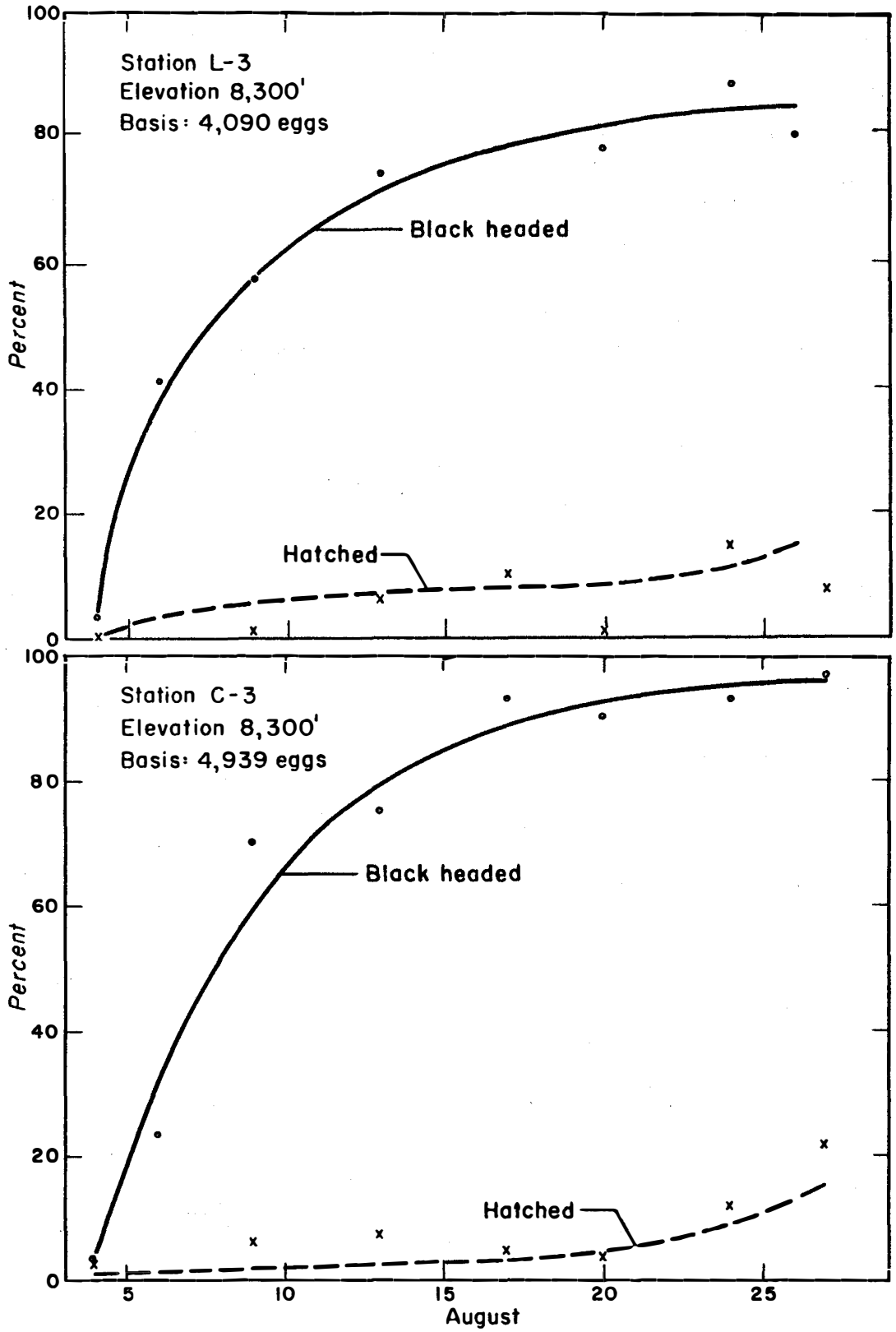

Figure 5.--Development of needle miner eggs to black-headed stage, and hatching at two representative stations.

Once spraying began, information on egg development helped to guide the sequence of spraying the various units. The first units to be treated were those at the lower elevations (around 8,100 feet), for the records showed that at these elevations the number of eggs in the blackheaded stage was well above 80 percent by the starting date. The last units to be sprayed were those at the highest elevations, and by August 28 when they were treated, egg development to the blackheaded stage or beyond approached 100 percent at all stations.

Close observations of the eggs also served as a basis for extending the spraying period 3 days beyond the 10-day limit originally specified. These observations revealed that development was delayed enough by a period of cool weather (figure 6) to make this extension practicable.

To some degree, decisions on spray timing were influenced by the data taken on incidence of the egg hatch. The counts showed that the number of hatched eggs in the samples increased after August 1, and that when spraying ended the average hatch for all stations was 16 percent. This information is not considered very reliable however, because the remains of the egg after the larva emerges are very fragile and hard to find. Consequently, the counts are apt to be in error.

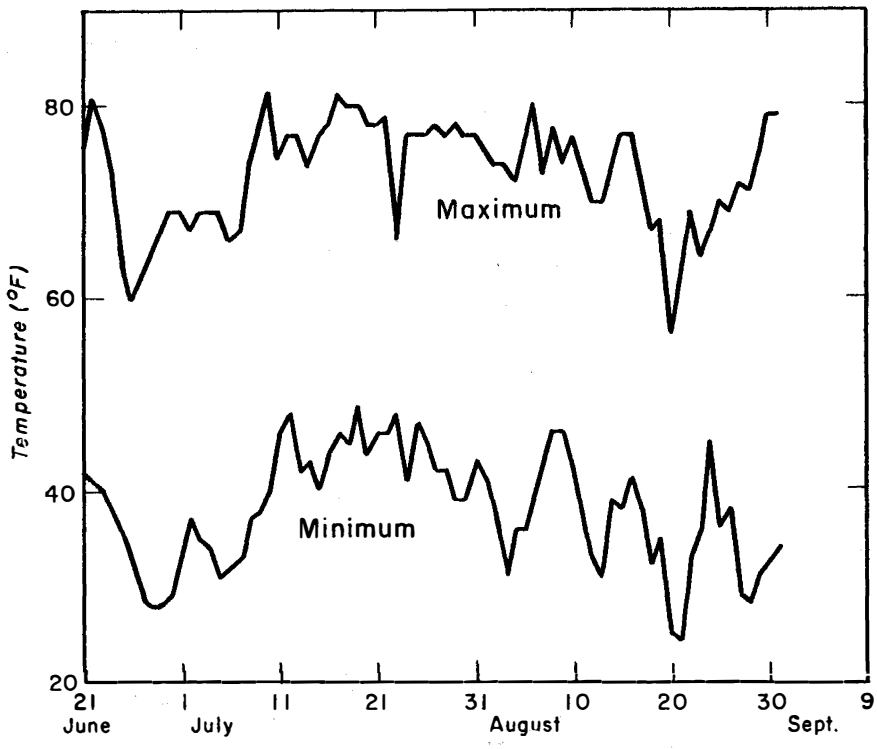

Figure 6.--Maximum and minimum air temperatures at Tuolumne Meadows, June 21 to August 31, 1959.

SPRAY OPERATIONS 3/

EQUIPMENT AND SERVICES

Whirl-Wide Helicopters, Inc., Fresno, California, was the successful bidder for the job of applying the spray. One Hiller 12-E, N5342V (figure 7) was provided for the first phase of the operation, and an additional 12-E, N5334V, was furnished for the larval spray.

United-Heckathorn Company, Richmond, California, was the successful bidder for the formulation, transportation, and handling of the insecticide.

CALIBRATION

Helicopter N5342V arrived at Tuolumne Meadows equipped with an Agavenco spraying system, consisting of a centrifugal pump operating off the engine accessory section, twin interconnected Fiberglass spray tanks with a capacity of about 50 gallons each, and a 28-foot spray boom located above the landing skids just aft of the cabin (figure 8). Helicopter N5334V was similarly equipped, except that its spray tanks were metal and the boom length was 30 feet.

The helicopters were calibrated to deliver the proper amount of spray for the 20-gallon per acre dose required. Calibration of N5342V was done according to standard field procedure, with the aircraft flying at right angles to a line of oil-sensitive cards placed 10 feet apart. Because of critical time limitations, N5334V was calibrated during its initial spray runs. The data for both aircraft are shown in table 3. Figure 9 shows a typical pattern of the spray cloud as delivered by the Hiller 12-E.

The heavy dose made it necessary to expose the oil-sensitive cards for only a short time, in order to observe the droplet size directly beneath the line of flight. The full amount totally covered the cards, making an assessment of gallons per acre impossible by this method. The droplet size produced by both aircraft appeared to be within the usual limits of 150-300 microns MMD.

SAMPLING THE INSECTICIDE

Park personnel took samples from each lot of insecticide as it was delivered. Some difficulty was experienced in obtaining a malathion content analysis, with the result that only one sample was analyzed. However, this one check, made by the U. S. D. A., ARS, Plant Pest Control Division, Pesticides Regulation Section, Washington, D. C., showed a satisfactory malathion content.

3/ For a detailed account of the operational phases of the project see "Insect control section extracted from annual forestry report of Yosemite National Park for the calendar year 1959" by Robert H. Sharp and Robert J. Smith, Yosemite National Park. Report 6A-1.

Figure 7.--Helicopter N5342V and spray storage tanks.

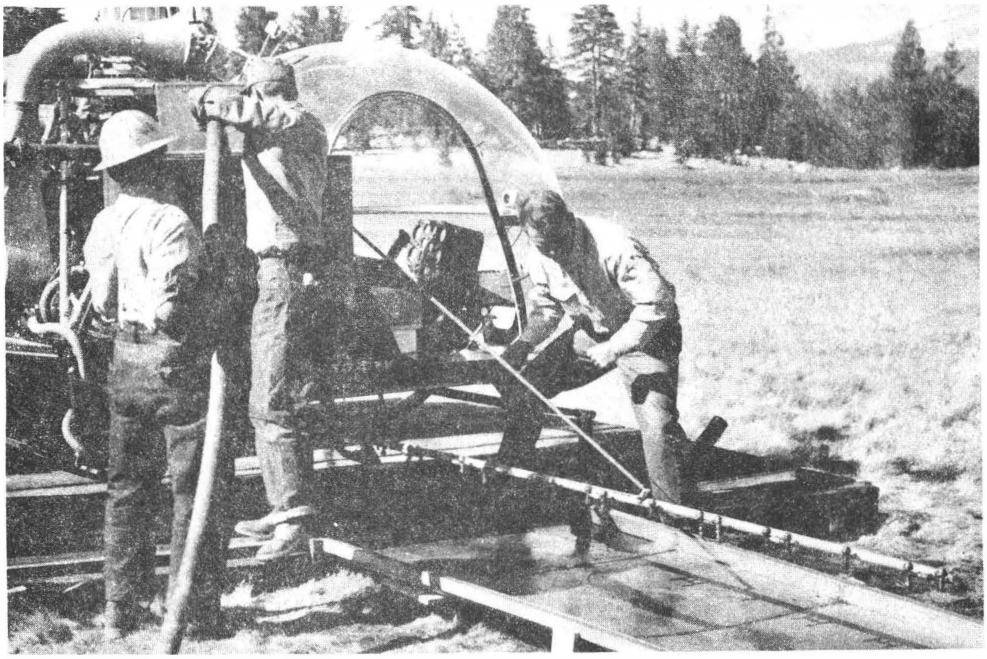

Figure 8.--Loading helicopter N5342V, 1959 Yosemite needle miner control project. Note position of spray tank, boom and nozzles.

Table 3.--Spray equipment performance in calibration tests with Hiller 12E helicopters (dose 20 gals./A)

Date	Aircraft	Boom length	Number nozzles 1/	Pump pressure	Flight speed	Flow rate	Nominal swath width
		Ft.		P.s.i.	M.p.h.	Gal./min.	Ft.
Jul. 14	N5342V	28	28	40	50	36	18.0
Jul. 15	"	28	43	40	45	42	23.3
Aug. 16	N5334V	30	38	45 (est.)	45	39	21.6

1/ All nozzles equipped with D-6 orifices and #45 discs, and directed downward.

Figure 9.--Spraying for needle miner control near Tuolumne Lodge, Yosemite National Park, 1959.

CHECKING COVERAGE

Park crews maintained close control over the spray application. The day before a block was to be sprayed, lines of oil-sensitive cards were laid out in the block in order to check on spray coverage. Suggested card lines were drawn on the photos and the photos were used in the field by the crews setting out the cards. Cards were placed in openings, and were held down with a rock or stick on one corner, approximately one card for every 20 acres. The quality of the spraying as indicated by the cards was such that no repeats were necessary.

A radio net set up by the Park provided communication between the spray blocks being treated, observers on vantage points, and the heliport.

APPLYING THE SPRAY

The moth spraying was done during the period July 15-24, and the larval spraying August 15-28. Daily operations began about as early as visibility was adequate - around 5:30 a.m. daylight time during July, and 6:00 a.m. in August, and were called to a halt when winds or heat prevented the spray from settling in a satisfactory manner. This occurred generally around 10:00 a.m.

The Hillers were able to carry between 65 and 95 gallons of spray per load, depending on winds, air temperatures, and the characteristics of the heliport being used.

MEASURING THE EFFECTS OF SPRAYING

SAMPLING INFESTED TIPS

The effectiveness of the spraying in controlling the needle miner was determined in accordance with procedures worked out during previous seasons. It involved running a series of lines through spray areas and comparable check areas. Sample trees were chosen along these lines, and the needle miner populations in these trees were evaluated before and after spraying.

Eighteen sample lines were established; four of these were in untreated areas, and the remaining fourteen were control areas. These lines were designated by letters; their locations are shown in figures 1 and 2. At least 100 sample trees were chosen for each of the three treatments - moth spray, larval spray, and unsprayed. All lines except lines O, P, Q and R were established with a 3-man crew during the period July 2-6. Lines O, P, and Q were established on July 10 with a 2-man crew, and line R, sampled only after spraying, was run on September 26, with a 2-man crew.

The lines in the unsprayed areas consisted of 25 sample trees each, spaced at 1-chain intervals. The lines within the sprayed areas, except line R, were made up of varying numbers of trees spaced at 2-chain intervals. Line R was made up of 20 trees, 1 chain apart. The lines were strung and each tree was tagged and numbered with a yellow tag, on which was marked the line designation and a serial number for the tree. In selecting sample trees the aim was to choose only ones that had an ample supply of infested foliage at 14 feet above ground, a point conveniently reached with pole pruners.

Four tips, long enough to include the 1957 and 1958 whorls of foliage, were clipped from each tree, one tip from each of the four cardinal directions. These were put in 5-inch by 7-inch glassine bags and taken to the Tuolumne Meadows field laboratory where the actual population counts were made. Care was taken to prevent undue mortality to the insects in the samples before they could be examined. In the field the bags of tips were carried in a packsack, which was kept out of the sun as much as possible. At the laboratory they were stored in the shade until population counts were made.

All the precontrol material was collected and examined from July 2 to July 12, the samples as a rule being examined not later than 3 days after they were collected. The postcontrol samples were cut by a 2-man crew on September 24, 25 and 26, and population counts were made with a 6-man crew, all on the 26th. It was not felt that handling was a mortality factor in either sampling.

Examining the tips for live and dead insects was done essentially the same way for both the pre- and postcontrol surveys. The former involved both larvae and pupae, whereas in the latter only early instar larvae were present. A random sample of 10 needles was drawn from the 1957 and 1958 foliage on each tip. In a few instances in the postcontrol survey when neither 1957 nor 1958 foliage remained, samples were taken from the 1959 foliage. The number of mined needles was determined by eye, and the insects were dissected from their mine with a pin or teasing needle, under a binocular microscope, and classified as live or dead. In the case of the precontrol survey, the needles were candled by the use of a light directed through the mined needle outlining the insect within. Healthy larvae could generally be stimulated to move with a pin prick, and ability to move normally was used as the criterion for a live larva. It was generally necessary to puncture the pupal skin to determine whether or not a pupa was healthy; dried, shriveled specimens were called dead; full, healthy-appearing ones live. Abandoned pupal cases were considered live insects. The number of mined needles per 10-needle sample was recorded, along with the number of live and dead insects.

Operational factors dictated certain changes from the original sampling plan, which called for all the area north of Tuolumne Meadows being sprayed in the first phase of the job, and that south of the

Meadows and west to Tenaya Lake being done in the second phase. Consequently, lines A, B, and C were established as moth-spray samples.

However, as can be seen from figure 1, part of the area north of the Meadows was not sprayed until the second phase of the operation. This resulted in portions of lines A, B and C being covered by different treatments, and necessitated adjustments, including adding trees for the postcontrol sample along lines A and B in order to maintain a 100-tree sample for the moth spray.

DROP CLOTHS

Information on the effects of the spraying, derived from sampling infested tips, was supplemented in the moth control area by collections from drop cloths. The main purpose of these was to determine whether or not any needle miner moths were killed. Nine of these drop cloths, each 3 ft. x 6 ft. in size, were set up to catch insects falling to the ground during the moth-spray period. Four of the drop cloths were established in check areas and five in areas to be sprayed. 4/ Their locations are shown in figures 1 and 2.

The drop cloths, cut from light muslin, were each stapled to the tops of four 2 x 2 posts, at a height of about 2 feet from the ground. A stick or rock was put in the center to keep the cloth from flapping in the breeze and throwing out the insects, and the posts were sprayed with chlordane to prevent ants from getting at the catches. This had been a problem previous years. Also, a deer repellent was applied to trees and rocks in the general area of the drop cloth, and to the posts. Deer had taken out the cloths in previous tests, but this season only one drop cloth was damaged. Whether this denotes effectiveness of the repellent or a more permissive attitude on the part of the deer is not known, as there were no checks. At any rate, deer were only a minor problem.

Drop-cloth collections were made throughout the moth-spraying period and for about 2 weeks thereafter. The collections included not only needle miner moths but a great variety of other forms of insect life which were killed by the spray. Catches were gathered up with an aspirator and stored in $\frac{1}{2}$-pint ice-cream containers with paradichlorobenzene until they could be segregated. This was done later at Berkeley by Donald Linsdale, a University of California graduate student in systematic entomology. It took him about 48 hours to separate and classify the material.

4/ Similar observations during the larval-spray period were made by Dr. A. D. Telford, University of California specialist studying biological control aspects of the needle miner problem.

RESULTS AND DISCUSSION

The degree of control resulting from the treatments, corrected for natural mortality by Abbot's formula, was 89.9 percent for the moth spray and 69.7 percent for the larval spray. The data population sample from which these percentages were computed are summarized in table 4.

The results of both treatments indicate that protection of the sprayed areas from severe defoliation should equal or exceed that obtained in earlier tests. The best previous tests, both against the larvae and the moths, have given only about 70 percent control, but this has been sufficient to prevent severe defoliation for at least 2 years. The larval spray in the 1959 operation produced about the same degree of kill and should be equally satisfactory. Control of the moths, on the other hand, was considerably better than in any previous test. Better control in this case is probably the result of the larger size of the area treated, as compared to the small size (20 acres) of the areas treated in the pilot-plant tests. It is reasonable to think that the larger the treated area, the less that invasion by moths would tend to be a factor in reinfesting it.

The immediate results of moth spray were dramatic. Needle miner adults commonly cluster along the tree branches during the daytime and only become active at night. Prior to spraying, shaking a tree during the day would produce a cloud of moths, disturbed from their resting positions, swarming around the tree. Within minutes after the spray reached the ground, the moths became irritated and were very quickly overcome. A veritable snowstorm of moths continued for 30-40 minutes following spraying, and occasional individuals were still dropping from the trees 24 hours later.

Observations 48 hours after spraying disclosed only an occasional moth in areas previously heavily populated, and a search 9 days later in one area failed to turn up any living specimens. By this time, of course, natural mortality also had had some effect. It is inferred from these observations that what residual population remains in the moth-spray areas is largely a result of oviposition prior to spraying.

The effect of the spraying on the moths and on one of the most common parasites of the needle miner (Copidosoma sp.) is illustrated by data from the drop-cloth collections (figures 10 and 11). As shown in these charts, relatively few moths or parasites were collected in the untreated area, but large numbers of both were collected after the spraying in the treated area.

By far the largest number of moths killed by the spray were taken on the days when spraying was done. The number of Copidosoma sp. caught at the same stations was not great during the spraying period, because the development of this parasite lags somewhat behind that of its host and the majority of the adults had not appeared by then. However, one

Table 4.--Number of needle miners in samples before and after spraying with malathion, by treatment. Yosemite National Park, 1959.

Sample lines		Number of 10-needle samples		Mean number live insects/sample		Percent control (Abbots formula)
		Prespray	Postspray	Prespray	Postspray	
Moth spray						
	A	68	164	2.21	.24	
	B	176	152	2.57	.34	
	C	128	8	2.29	.00	
	R	--	80	--	.70	89.9
Total		372	404			
	Mean of all samples			2.35	.37	
	Standard error/mean			±.09	±.13	
	Percent sampling error 1/			3.8	3.8	
Larval spray						
	A	40	40	1.15	0.32	
	B	36	52	3.38	.35	
	C	60	60	1.48	.58	
	E	40	40	3.37	.67	
	F	40	36	1.60	1.36	
	H	40	40	3.57	1.57	
	J	40	12	3.17	2.25	
	L	40	40	1.97	.90	
	M	40	40	2.23	.75	
	N	40	40	2.07	.92	
	O	40	40	3.32	1.10	
	P	40	40	2.05	2.07	
	Q	40	40	2.80	3.42	69.7
Total		536	520			
	Mean of all samples			2.43	1.15	
	Standard error/mean			±.09	±.07	
	Percent sampling error 1/			3.60	6.70	
Check						
	D	100	100	.40	1.32	
	G	100	100	1.52	3.02	
	I	100	100	2.23	3.65	
	K	100	100	1.46	.75	--
Total		400	400			
	Mean of all samples			1.40	2.18	
	Standard error/mean			±.07	±.09	
	Percent sampling error 1/			5.30	4.30	

1/ Sampling error at 68 percent confidence level.

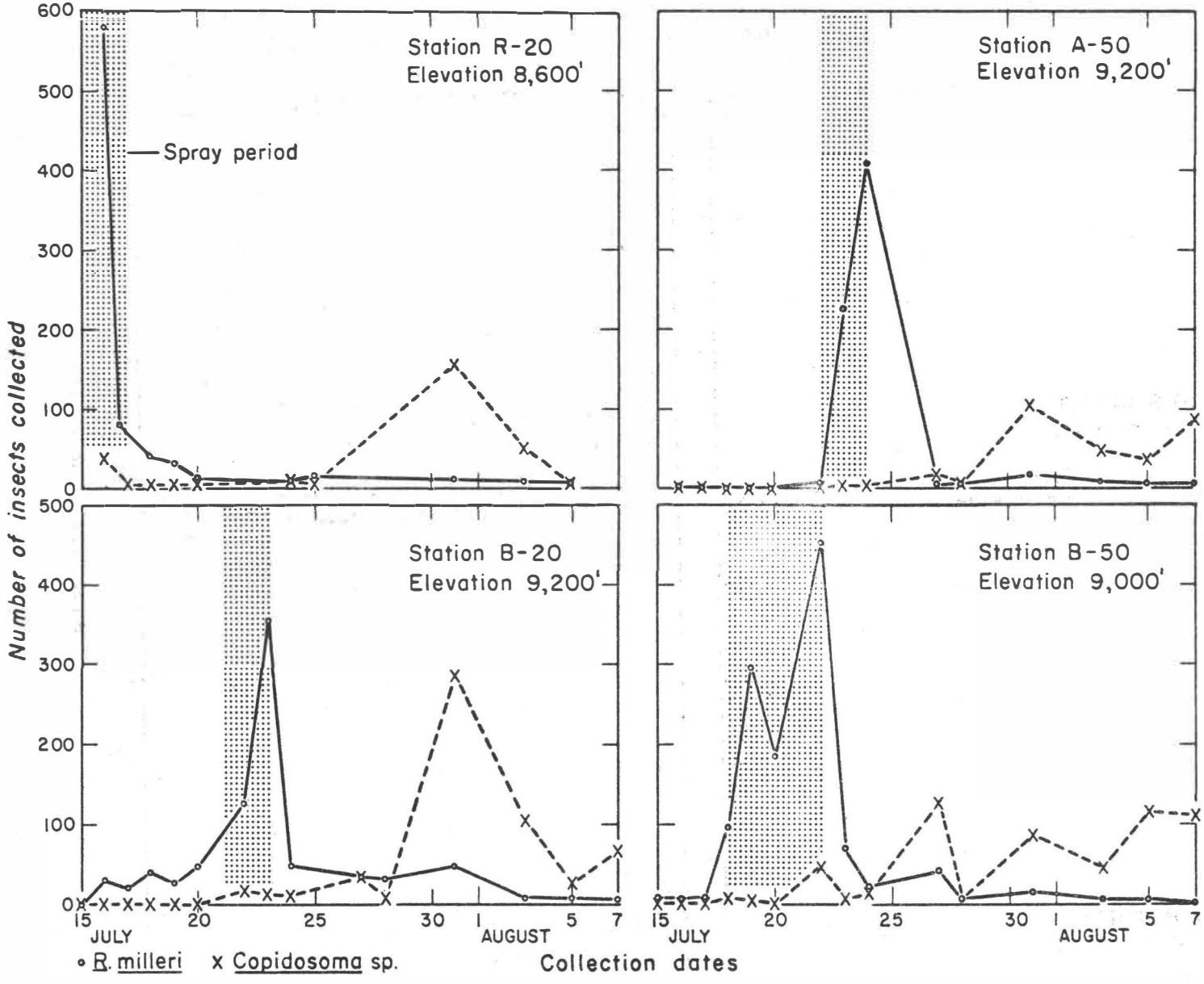

Figure 10.--Collections from 3 ft. x 6 ft. drop cloths in spray areas. 1959 Yosemite needle miner control project.

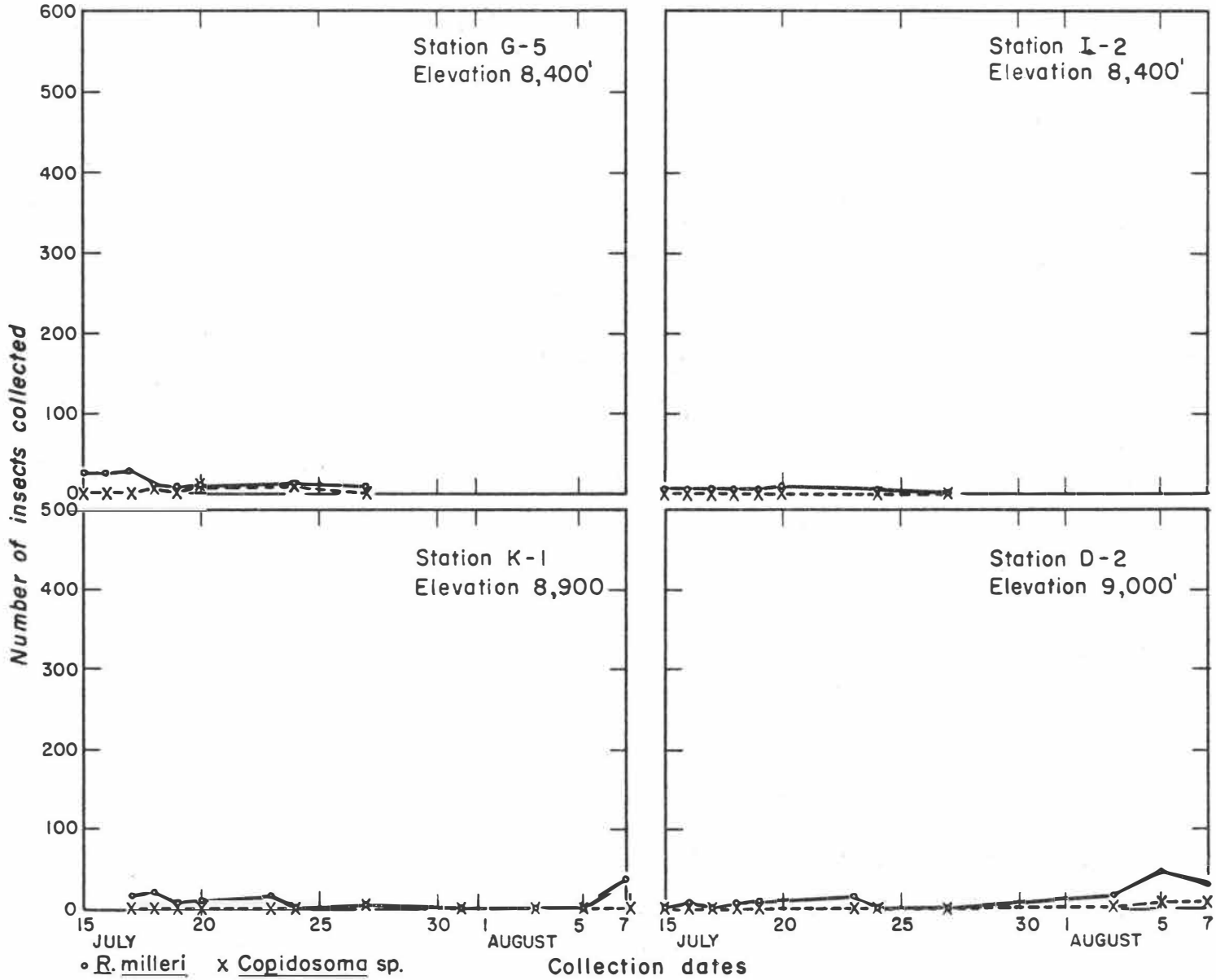

Figure 11.--Collections from 3 ft. x 6 ft. drop cloths in unsprayed check areas. 1959 Yosemite needle miner control project.

to two weeks later, when Copidosoma sp. adults were most abundant, the number caught in the sprayed area increased considerably, indicating a residual effect of the malathion.

In addition to the needle miner and its principal parasite, many other kinds of insects were collected from the drop cloths. When these were sorted, over 125 separate species or forms were found (table 5). None showed up in the collections with any degree of regularity, however.

Spraying to control needle miner larvae following their emergence from the eggs had an unexpectedly severe effect on the survival of unhatched eggs. This came to light when it was discovered in examining eggs from sprayed areas that many had an oily sheen on the surface and were slightly abnormal in color a week after spraying. Two to three weeks later the affected eggs were darkened and shriveled. Although no attempt was made to assess the effectiveness of spraying on the basis of egg mortality, the ovicidal effect of malathion is demonstrated by data collected from sprayed and unsprayed areas (table 6).

These results point to the need for additional testing to determine the possibilities of controlling the needle miner during the egg stage with sprays. If this were possible, it would permit extending the length of time for control work against the eggs and young larvae by 10 to 14 days.

Table 5.--List of insect species and forms collected in drop cloths in areas sprayed to control needle miner adults, Yosemite National Park, 1959. (Needle miners and Copidosoma sp. are excluded.)

Group	No. of different species of forms
Hymenoptera	
Tenthredinoidea	3
Ichneumonoidea	11
Braconidae	3
Chalcidoidea	20
Mymaridae	1
Pteromalidae	1
Platygastridae	1
Proctrotrypidae	1
Formicidae	3
Diptera	
Unknown	2
Chironomidae	8
Trypetidae	2
Empididae	4
Rhagionidae	1
Anthomyiidae	3
Syrphidae	1
Tipulidae	2
Hesperiidae	1
Tachinidae	1
Asilidae	1
Coleoptera	
Unknown	1
Dasytidae	3
Cantharidae (?)	2
Staphylinidae	1
Dermestidae	1
Hemiptera	
Unknown nymphs	12
Tettigellidae	6
Cercopidae	1
Aphididae	1
Lygaeidae	1
Miridae	9
Lepidoptera	
Unknown microlepidoptera	2
Olethreutidae	1
Neuroptera	
Raphididae	1
Hemerobiidae	4
Thysanoptera	3
Plecoptera	3
Collembola	1
Corrodentia	3

Table 6.--Needle miner egg mortality within three weeks after spraying in areas treated to control the larvae and in untreated areas. Yosemite National Park, 1959.

	Sprayed			Unsprayed		
Date	Location	No. eggs examined	Percent dead	Location	No. eggs examined	Percent dead
Sept. 2	L-4	73	71			
3	Plot G	180	94	C-1	100	5
	L-2	184	69	C-2	69	25
	L-1	107	45	C-2	35	9
				E.Cathedral	126	0
				Delaney	136	4
4	L-1	70	93	C-3	228	14
	L-3	80	95			
	Plot A	134	51			
8				C-1	86	0
				C-3	81	4
				C-4	69	0
9	L-3	201	100			
15	L-2	234	94			
17	L-1	34	100			
	Total	1,297			930	
	Mean		82			7